A Flight-Proven 2.4GHz ISM Band COTS Communications System for Small Sats

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Overview

- GeneSat Mission Overview
- Communications System Description
- Earth Station
- Design Analysis
- Space Qualification
- Flight Results
- Conclusions
GeneSat-1 Mission Overview

- Technology Demonstration to Validate in-situ Biological Research
- Triple-CubeSat Package
- Led by NASA Ames Astrobiotics Group
- Strong University Participation
- Launched December 16th 2006
- Successfully completed primary and secondary mission objectives
- Current Status: Operational
Communications System Selection

Why Industrial-Scientific-Medical (ISM) band?
- Licensing issues
- Fast Integration
- Low-cost
- Wide variety of COTS hardware
Communications System Description

- COTS MHX-2400 from Microhard Corp.
- 2.4GHz ISM Band
- Frequency Hopping Scheme
- 1 Watt Output Power
- Serial Interface
- Plug-n-Play Radio-Modem
Communications System Description

- In-house Antenna Design
- Circularly Polarized Patch Antenna
- Passive Attitude Control
Earth Station

- 18-meter Dish, only illuminated over 10 meters
- Owned by SRI International
- Computer-controlled tracking software
  - Pointing Error: 0.02 deg.
- Uses same MHX-2400 radio modem
Design Analysis

- Link Margin: ~10dB @ min. Elevation
- Access Time: 3.5 min Average, 6 min Max.
- Throughput: 9600 bps, can be increased
- Power Consumption: 1 Watt Rx, 4.5 Watt Tx
- Pointing Budget: 0.38 deg max. pointing error
- Security: built-in data encryption
Doppler Shift

- Max Shift for the mission: ~50KHz
- Tested in the lab: The radios can accommodate the shift
Path Delay

- Radio-Modems follow a frequency hopping pattern
- Propagation delay can put radios out of synch.
- Solution:
  - Set the Hop Interval and packet size so any packet transaction finishes before next freq. hop
• **Thermal-Vac Cycling**
  - Cycled in Thermal-vacuum Chamber
  - Survived -40° to 60° C
Flight Results

- Launched December 16th, 2006 on Minotaur-1 as piggyback
- 410km, 40.5 deg inclination orbit
- Successful link established using first TLEs provided by NORAD

Access Time Statistics:

<table>
<thead>
<tr>
<th>Access Time</th>
<th>Predicted</th>
<th>In-Flight Measured</th>
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<tbody>
<tr>
<td>Average</td>
<td>3’48”</td>
<td>3’04”</td>
</tr>
<tr>
<td>Max.</td>
<td>6’00”</td>
<td>5’10”</td>
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Flight Results

● Thermal Profile:

Max. Temp: – 34°C
Min. Temp: – 15°C

Transceiver:

● Max. Temp: 34°C
● Min. Temp: 15°C
Flight Results

- Link Margin Measurements:
  - Good Link Margin
  - Large Variations due to Passive Attitude Control

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Conclusions

- COTS Transceiver flown with no modifications
- Low Cost – Fast Integration
- Significant Earth Station infrastructure – but may be reduced
- Fewer licensing requirements given it is not an amateur band
- Not the best solution, but it may work for your mission
- Many universities/companies are planning on using this system in future missions
  - MAST Mission has already flown the Microhard Successfully
  - GeneSat-1 has been operating for 8 months
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